I.O.S.

R. R. S. CHALLENGER
CRUISE 79/5

10 April - 23 April 1979

Physical and biological sampling on the Nymphe Bank, Celtic Sea and in the vicinity of the Goban Spur

CRUISE REPORT NO. 81

1979

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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Wormley, Godalming,
Surrey, GU8 5UB.
(0428 - 79 - 4141)

(Director: Dr. A.S. Laughton)

Bidston Observatory,
Birkenhead,
Merseyside, L43 7RA.
(051 - 653 - 8633)

(Assistant Director: Dr. D.E. Cartwright)

Crossway,
Taunton,
Somerset, TA1 2DW.
(0823 - 86211)

(Assistant Director: M.J. Tucker

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INSTITUTE OF OCEANOGRAPHIC SCIENCES

R.R.S. CHALLENGER
CRUISE 79/5

10 April - 23 April 1979

Physical and biological sampling on the Nymphe Bank, Celtic Sea and in the vicinity of the Goban Spur using a batfish and continuous surface water sampling.

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Institute of Oceanographic Sciences,
Wormley, Godalming,
Surrey GU8 5UB

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SCIENTIFIC PERSONNEL

M.J.R. Fasham	IOS Wormley	Principal Scientist
P.R. Pugh	IOS Wormley	
J. Smithers	IOS Wormley	
V. Lawford	IOS Wormley	
P. Domanski	IOS Wormley	
P. Holligan	MBA Plymouth	
R. Head	MBA Plymouth	
G. Knight	RVS Barry	
J. Burnham	RVS Barry	
A. Wilson	SPL International	

SHIP'S OFFICERS

Master	P.H.P. Maw
Chief Officer	G.M. Long
2nd Officer	M.S. Putman
3rd Officer	C. Dixon
Extra 3rd Officer	R. Hagley
Chief Engineer	R.W. Anderson
2nd Engineer	I. McGill
3rd Engineer	C.B.A. Harman
4th Engineer	R.G. Whitton

OBJECTIVES

1. To measure the critical physical and biological parameters in the vicinity of the Nymphe Bank, Celtic Sea, during the developing phase of the spring phytoplankton bloom. The vertical and horizontal distribution of temperature, salinity and chlorophyll a would be measured using a 'batfish' profiling system, while the surface distribution of temperature, salinity, oxygen and nutrient concentrations, particle size distribution and chlorophyll a concentration would be sampled continuously from a pumped water supply (see Fig. 1 for sensor arrangements).

2. To carry out a similar sampling operation on the shelf edge in the vicinity of the Goban Spur to investigate the position and profiles of any shelf edge fronts.

ITINERARY

It was decided for logging purposes to divide the cruise into a consecutive series of legs and the timing and positions of these legs are given in appendix 1, and figs 2 to 6. Two types of vertical profiles were also given dip numbers; these were standard vertical profiles using the hydrographic winch and vertical profiles obtained by stopping the ship and allowing the batfish to sink to the full extent of the wire out. Details of these dips are given in appendix 2.

The ship sailed at 0800h/11.iv and set course for the Nymphe Bank. At 1300h the ship hove-to to deploy the IOS temperature probe, the underwater pump, SIMRAD transducer and P.E.S. fish. Some initial difficulty was experienced connecting up the underwater pump to the correct electrical supply but the system was eventually working at 1630h. The pumped water supply was successfully connected to the thermosalinograph, auto-analyzer, Turner fluorometer and HIAC particle counter. The PDP1134 computer sampling system was started and, after some initial bugs were cured, the surface temperature probe data was successfully recorded.

It was soon found that the pole carrying the SIMRAD transducer vibrated violently at speeds greater than 5 knots and so at 1830h the pole had to be recovered. It was also found that no signal could be observed from the P.E.S. fish and so water depth was recorded using the KRUPP echo-sounder in the scientific control room. The P.E.S. fault was eventually traced and from the 14/iv onwards water depth was recorded on the P.E.S. Mufax.

During the rest of this day we made course for the Nymphe Bank while work was carried out preparing the CTD/Batfish system and in wiring up the Digital Transmission System modules which were to be used to connect various analog data points to the 1134. At 0610h on the 12/iv we hove to at 51°10.3'N, 7°57.7'W while the batfish was prepared for launching. During the morning and early afternoon a number of trial runs were carried out and adjustments made to the batfish wing angle. It was also found that the hole cut in the batfish nose for the Chelsea fluorometer needed widening to avoid light from flash unit being reflected directly into the sensor unit. The system was finally in a working state at about 2200h and the first survey of the Nymphe Bank was begun.

A survey grid of 40 x 50 km situated to the south of the Nymphe Bank was decided on (fig. 3, legs 3-13) and the batfish yo-yo was set between 5 and 60m. The batfish, CTD and fluorometer data was sampled successfully by the 1134 system although some software problems were experienced which were never solved. The result of these problems was that on-line plots of calibrated temperature, salinity and pressure, but not chlorophyll could be obtained. Thus for the latter variable we had to rely on the analog output provided by the Gould recorder.

During 13/iv the Nymphe Bank survey was continued and was eventually finished at 0530h on the 14/iv. The survey showed that in the east the water column was stratified with medium chlorophyll levels (c.3$\mu g/m^3$) while in the west it was homogenous with low chlorophyll values.

The ship now hove-to to bring in the batfish and the CTD and fluorometer was taken out and transferred to the cage attached to hydrographic winch wire. The Plessey light meter and intake for a Flygt underwater pump was also fixed to the cage and then a number of dips (1-3) were made to obtain vertical profiles of temperature, salinity, light irradiance, chlorophyll fluorescence, nutrient concentration and particle size distributions down to 70m. The CTD and Chelsea fluorometer were then transferred back into the batfish which was relaunched.

Course was then set for the shelf edge (leg 14) at 1515h.

At 1740h the fluorometer ceased working and the batfish had to be recovered. It was found that the 'Marsh' Marine plug on the fluorometer had fractured due to being struck by the hydraulic ram. This was repaired but the fault persisted and it was discovered that the fluorometer interface in the CTD had burnt out necessitating a long repair. The batfish was eventually relaunched at 2232h.

At 1840h on the 15/iv the ship arrived at the shelf edge and altered course for the south. At 2045h the ship passed through a front; the surface temperature increasing from 10.5° to 10.8°C at a water depth of 1000m. The chlorophyll levels were extremely low in this region but a small change in level was noticed at the front. The ship continued south to 48°N 30°W and then altered course to the east and almost immediately passed through a second front taking the surface temperature up to 11.0°C. At 0450h on the 16/iv the ship altered course to the north to return to the shelf edge and passed over the two fronts again in the reverse direction arriving at the shelf edge at 0910h. It was decided to zig-zag northwards along the shelf edge in an attempt to map the line of the 10.5/10.8°C front. Two zig-zags were achieved and it was then decided to bring in the batfish to inspect the sensors. Unfortunately one wing of the batfish was damaged on recovery and a lengthy delay was experienced while this was repaired. During this period 50 polythene containers were filled with seawater for the IOS Standard Seawater Service.

The batfish was relaunched at 1907h on the 16/iv and the ship then continued zig-zagging onto the Goban Spur. The front was less sharply defined in this area and so it was decided to turn south-west to recross the shelf edge at the point at which thefront was first found on 15/iv,and course was altered at 0114h on 17/iv. However it was found that the sharply defined 10.5/10.8°C front observed on the 15 and 16/iv could not now be found , but had been replaced by a much more gradual horizontal temperature gradient. A further shelf edge crossing was made to the south-east where the same effect was observed.

At 1900h on the 17/iv the ship altered course back for the Nymphe Bank. During this long run it was decided to record the batfish data on the Digidata/Revox recorders only thus enabling some software and hardware development to be carried out on the PDP1134 system.

The course for the Nymphe Bank took us over the Great Sole Bank and it was noticed that the chlorophyll levels were higher here than on either side. At 0910h on the 18/iv intermittent loss of control of the batfish was experienced. The batfish was brought in and the cable was found to be faulty and it was decided to replace it with a new cable. This lengthy operation took until 2250h during which time we continued course for the Nymphe Bank.

At 2300h on the 18/iv the second survey of the Nymphe Bank area was begun (legs 32-42). The DTS hardware was now working properly and so it was decided to attempt to sample EM log, gyro, nutrients, oxygen and fluorescence into the 1134. It was found that sampling the log and gyro caused software problems which could not be solved and so sampling of these variables had to be abandoned. However the other data were sampled from this time to the end of the cruise. In the intervening six days between this survey and the first, the density stratification had intensified and the maximum chlorophyll a levels had increased to around $10 mg/m^3$. However a SW to NE gradation from low to high chlorophyll, similar to the first survey, was observed. The last leg of the survey was repeated again to obtain some idea of short term temporal variations and the survey was finished at 0817h on the 20/iv.

The batfish was brought inboard and the CTD and fluorometer transferred to the profiling cage. A series of vertical profiles was then made at the eastern ends of the batfish survey legs. At each dip a fast profile to around 70m was followed by a slow ascent stopping every 2m for about 50 seconds to allow the pumped water to circulate fully around the shipboard sensors. These dips were completed at 1922h and the ship hove to till 2300h so that the third Nymphe Bank survey (legs 43-51) could be started at the same time of day as the second.

The third survey was completed at 0026h on 22/iv although a small section of the last leg was lost due to a batfish fault. The ship then set course for Lundy Island continuing to Batfish. At 0421h control problems were experienced with the batfish and it had to be recovered. These problems were traced to the cable terminator joint which was re-made and the batfish relaunched at 0613h. No further problems were experienced during the run to a position close to Lundy Island where the batfish was recovered and all sampling finished. The ship then sailed for Barry and docked in the early morning of the 23/iv.

GEAR REPORTS

1. PDP 11/34 Data Acquisition System (J. Burnham and A. Wilson)

(a) General

Collection of scientific data commenced at 1250h 11/iv and ceased at 1120h 22/iv; a total of 262.5 hours. The PDP 11/34 was in the data acquisition mode for 210 hours, during which 5 hours 40 minutes of data were lost in 19 separate incidents. In approximately 12 of these, the system looked up and/or crashed and in the remainder, raw data sampling programs exited without warning because of bad disk transfers. There were a further 22 incidents in each of which a few seconds of data were lost through the same disk transfer problems. Four periods of approximately 1 hour each were available for development in the first 3 days. These occurred at convenient breaks in batfish sampling. 27 hours of development time were available from 2000h 17/iv, while Digidata was used to log batfish data. The system was out of service from 0810h 20/iv until 0550h 21/iv for disk drive repairs after which bad disk transfer incidents were considerably reduced. Digidata and Revox were used as backup batfish/CTD logging systems throughout the cruise.

(b) Software

Several new programs were written before the cruise i.e. for logging and calibration of surface irradiance, for logging and calibration of analogue data, for logging of EM log and gyro, for logging data from the new Magnavox Satellite receiver. These could be tested only when the system was logging but could only be modified when the system was not logging. Debugging was therefore a lengthy process. Additionally as system common had been extended before the cruise, many programs needed to be rebuilt at sea. Most programs were performing satisfactorily at the start of the cruise and all by the seventh day of the cruise, except for the acquisition of EM log and gyro. Some development testing was possible during data logging but this led to a considerable number of system lock-ups as CAMAC appears to be sometimes incapable of dealing with interrupts from several terminals. It seems necessary to consolidate past work on the system and to produce comprehensive documentation. The system appears to be I/O bound on drive 1. This situation could be eased. The PDP 11 generally needs to be tuned up to its acquisition environment.

(c) Hardware

This cruise was dominated by a series of software malfunctions, whose origin was due to faulty hardware. Most of these faults were attributed to a gradual decline in performance of the RK05 flying head disc drive 1, so much so that the system was off the air for 24 hours to enable repairs to be made. The drive heads were found to be badly out of alignment and most of the time was spent making adjustments to the flying head timing. The siting of the machine severely restricted this work and further damage to the machine was sustained before it was finally repaired. In future the four boxes which comprise the computer essential elements should be installed at bench height with at least 4 feet of access space at the front.

Not all the faults were attributed to the computer itself. The disc diagnostics revealed that failure occurred due to a temporary loss (45ms) of a.c. and/or d.c. power. The computer was powered via the ships stabilized supply but this may not have been good enough. No equipment was available to check the regulation of the supply but, audible changes in the computer fans and visible slowing down of the disc flying heads when even the mildest change in load took place strongly suggested that the supply was not adequate for the job.

The new data transmission system was successfully installed on the system for the first time. After the initial correction problems had been overcome eight analogue channels and one digital channel were successfully interfaced to the computer

2. The Batfish System (V. Lawford)

The batfish was launched late in the afternoon of the 12th April after a day spent in trials and setting-up procedures. The fluorometer was fitted to the vehicle, but the water sampling system was still not working correctly, and so was not fitted.

During these trials a shortcoming in the design of the new Lebus winch became obvious; while the fast speed is excellent for paying out and recovering long lengths of cable and the inching speed is most suitable for accurate positioning and small adjustments of cable length, neither speed is suitable for handling the vehicle in the critical distance between sea and sheave. For this an intermediate speed is required, about four times the present inching speed.

Except for a brief inspection to ensure that all was well, the batfish stayed in the water until the completion of the first survey of the Nymphe Bank. This survey took some 37 hours to complete. Length of cable out varied between 90m and 140m, the vehicle being set to oscillate between depths of about 5m and 65m with periods of 2 to 2½ mins. During this run and for the remainder of the cruise, cable tensions were controlled to a normal working maximum of 700Kg and ship speed was maintained between 6½ and 7 knots. Some difficulty was experienced in maintaining a smooth and regular profile, particularly with cable lengths in the region of 120m. The slip rings fitted to the winch were of great value when making adjustments to cable lengths as they allowed the regular oscillations and the data collection to proceed uninterrupted.

During this survey the new Laser Lines chart recorder was set up and operated. It was found to give a very clear trace and due to its lower frequency response than the Gould recorder, it gave a better trace for the chlorophyll data which contained a lot of high frequency signal. Throughout the cruise this recorder was in use from time to time in areas of special interest. It was usually run at a speed of 20mm/sec - four times faster than the Gould recorder. The only drawback found with this recorder is the comparatively short length of chart that is displayed after writing and before the take up roller.

On recovery of the batfish during the early hours of the 14th, it was found that the bellows on the front of the hydraulic unit had hardened and fractured, allowing the oil out and the whole of the forward buffer volume to be flooded with sea water. The bellows, which is a PVC dipping, had become quite brittle and rigid, possibly due to a fault in the curing process during manufacture. It was found that the fluorometer was giving positive readings when on deck and this proved to be due to reflections from the inside of the nose cone. The hole in the nose cone was enlarged until zero readings were obtained in air. During the recovery the vehicle sustained two hard knocks against the ship's counter. These caused some cracking in the GRP of the tail unit and the loss of two cores in the towing cable, probably in the area of the termination block at the batfish towing bridle. These knocks were primarily due to the lack of a suitable winch speed for this part of the operation.

The batfish was launched again during the evening of the 14th for the start of the run from the Nymphe Bank out to the shelf edge but had to be recovered within two hours as the chlorophyll signal was lost. This was found to be due to a broken pin in a Marsh and Marine plug on the back of the fluorometer, this in turn had been caused by the ram of the hydraulic unit touching the plug at the very front of its stroke. It was found necessary to enlarge the hole in the nose cone still further to allow the fluorometer to be moved further forward in the vehicle thus giving more clearance between the plug and the ram. At the same time a fault developed on the fluorometer interface board in the CTD that required substitution of components.

The vehicle was finally launched, with the water sampler fitted just before midnight with 180m of cable out. A 'yo-yo' of just under three minutes duration between 5m and 70m was set up and with only small alterations to the controls was maintained for 38 hours at which time the survey ended.

During this run occasional individual spikes began to appear on the record; this was put down to dirt on the slip rings as movement of the winch seemed to stop the spikes. After 38 hours in the water it was decided to retrieve the batfish and inspect the vehicle, particularly the bellows unit, that had failed on the previous run. Unfortunately, during recovery, the starboard wing was damaged against the ship's counter. Inspection of the hydraulic unit showed that it was in excellent condition. The starboard wing needed extensive repair in the same area that it had been damaged last year. All the cable cores were found to be intact and it was inferred from this that the spikes that had been evident before were probably due to dirt on the slip rings. The water sampler had not fired as the junction box had flooded. In fact the lid of the junction box had very nearly lifted off the tube. It was not apparent why this had happened.

The batfish was launched again during the evening of the 16th with 190m of cable out and the water sampler fitted. 38 hours later a major cable fault appeared and the vehicle was recovered. Two cores in the cable were found to be short circuited, several others were showing low resistance. Also it was noticed that there was severe corrosion on parts of the fluorometer casing, in particular the aluminium rings that retain the two lenses. A new ring was built and fitted in place of the worst affected and a small zinc anode was fitted to the casing. Much of the corrosion was starting at sharp edges on the casing.

Once again the water sampler had not fired and again the junction box had some water in it. The junction at the fish end of the cable was rebuilt, but resistances were still rather low, the lowest being little better than 20K. However a launch after lunch on the 18th quickly showed that the cable had damage that had not been found. It appeared as if the cable was flooding with sea water and several of the cores were still going to very low resistance. The spare cable was wound on to the winch and connected through the batfish; this operation took several hours and it was nearly midnight before the batfish was launched again. All seemed to be well.

In the early hours of the following morning, waste disposal from the ship was the cause of a typewriter ribbon becoming entangled in the batfish impeller, which necessitated a brief recovery and relaunch. The survey was then completed without further mishap by about 0900h on the 20th. This was the second complete survey of the Nymphe Bank. Again it was found that the water sampler had not fired though this time the junction box had not flooded. The remainder of the vehicle was in good condition, except that the fluorometer was still showing signs of corrosion in some parts. It was obvious, however, that the fitting of the anode had considerable but rather local effect.

During the day work was carried out on the water sampling system and several brief trials carried out. It was found that the flooding of the junction box had degraded some of the electronics. However the circuit was tuned so that the sampler could be fired, if rather irregularly.

The batfish was launched at 2300h for the start of the final survey of the Nymphe Bank. Just after 0900h the next day the control of the hydraulics was lost and the batfish recovered. It was found that there was a break in the cable between the cable termination at the bridle and the nose cone. This was due to the change in stiffness of the cable at the end of the armouring. Usually the inner layer of armouring is continued through the nose cone; however on this occasion the armouring had been cut rather short and did not reach as far as it should. Repairs were soon made, though they were of a temporary nature, and the batfish relaunched. Unfortunately a similar problem occurred at the same point a few hours later, but only took one and a half hours to repair. On the occasion of the first recovery and repair, it was found that the water sampler had operated successfully and four water samples were obtained from different depths and from different parts of the survey area. The survey was finally completed at midnight on the 21st and course set for Lundy with the batfish still out. The tow was continued until the mixed region of water was reached shortly after lunchtime on the 22nd April when the batfish was recovered for the last time.

Conclusion

During the cruise the batfish was in the water supplying data for a total of 183 hours; this represents 60% of the total cruise time. During the cruise the total down time of the system due to breakdown and repairs was 25 hours or some 13% of the towing time. Except for one short period of horizontal towing the batfish was used in the 'yo-yo' mode, the yo-yo period being between 2 and 3 minutes; maximum and minimum depths of the yo-yo were around 50m and 5m respectively. Therefore during the entire cruise some 4500 oscillations were made along a track some 1200 miles long. During the whole time measurements were made with both the CTD and the fluorometer of Depth, Temperature, Conductivity, and Chlorophyll at a rate of 16 measurements of each parameter per second, a total of 4×10^7 measurements.

Unfortunately, due to a number of small faults in both cabling and electronics, the water sampler only provided one set of samples. However, normally a water bottle sample was taken when launching and recovering the batfish, at a depth of around 8m which will enable a number of calibrations of the CTD conductivity cell to be made. On several occasions the ship was slowed down when the batfish was in the water and the vehicle allowed to sink to the extent of the towing cable, allowing measurements to be made down to about 150m.

TABLE 1 - RECORD OF BATFISH USE - CHALLENGER CRUISE 5/79

In sea time/day no.	Recover time/day no.	Duration Hours/min.	Reason for recovery	Duration of Data recording
1300/102	1340/102	0 40	No wing control	
1440/102	1500/102	0 20	Reset wing angle	
1600/102	1605/102	0 05	Reset wing angle	
1610/102	2200/102	5 50	Inspection	5 50
2210/102	0530/104	31 20	Survey end	31 20
1510/104	1740/104	2 30	Fluorometer plug	2 20
2230/104	1320/106	37 50	Survey end	37 50
1900/106	0900/108	38 00	Cable fault	38 00
1435/108	1450/108	0 05	Cable fault	
2250/108	0020/109	1 30	Impellor snagged	1 30
0040/109	0820/110	31 40	Survey end	31 40
2300/110	2140/111	22 40	Cable fault	22 40
2340/111	0430/112	4 50	Cable fault	4 40
0610/112	1300/112	6 50	Survey end	6 50
				183hr approx.

3. HIAC Particle Counter (P.R. Pugh)

The Hiac Model PC320 Particle Size Analyser was used throughout the cruise. The CMB 600 sensor, which measures the size of particles in the 10-600μm diameter range, was used exclusively. The threshold settings for the nine counting channels were adjusted so as to represent a logarithmic increase in particle diameter within this size range. The flow rate through the sensor was set at ca. 850ml min^{-1}, and monitored constantly by an E.M. sensor. There was an initial problem with air in the system when water was being drawn from the "bucket" on deck, and so for most of the cruise the ship's sea water supply was used directly.

Prior to this cruise, the particle count data had been displayed on a paper printer, and this required a minimum of an 8 second time period between successive counts. Because of the desirability, from the point of view of subjecting the data to spectral analysis, of reducing both the sampling period and more importantly the period between counts to a minimum a new method of recording the data was used. Thanks to the work of Eric Darlington, with Dave Edge, a new clock interface had been built which enabled the recording of the data onto punch tape. This method also obviated the necessity of manually transferring the data to a computer. At full speed this system reduced the recycle time to 2 seconds, with, if desired, a one-second counting period. In practice, and faced with the vast amount of data which could be collected, the sampling period was set to 15 seconds with a 5 second recycling period.

The system worked well for most of the cruise, except for some minor punching errors caused by a loose board. During the cruise a further option was added which enabled the selection of the time period during which the particle counter displayed the count data. This enabled the paper printer to be switched into the system to record the counts while the punch tape was being changed, and, thereby, reduced the loss of data to a minimum. However, it was probably as a result of this modification that an error crept into the punched data, which meant that the results for the third survey of the Nymphe Bank were uninterpretable.

A preliminary examination of the particle count data for the first two surveys of the Nymphe Bank indicate some interesting changes in the distribution of the particles, geographically, temporarily and in relation to their size. Little activity was noted in the first survey, a feature which was also shown by the fluorometer records. However, by the time of the second survey the particle concentrations had changed markedly, in agreement with the fluorescence, but in addition the relative contributions which the various particles sizes made showed interesting trends which could not be indicated purely from a study of the chlorophyll concentration.

RESULTS

1. Nymphe Bank Surveys (P. Holligan)

(a) Hydrography - On each of the three surveys the distributions of salinity (range 34.75 to 35.00‰) and bottom temperature (range 7.25 to 8.75°C) were very similar, with the coldest, freshest water occurring to the north east. Between the 13 and 19 April the surface temperature rose between 1.0 and 1.5°C during a period of warm and calm weather, and this is considered to have been due to local heating of the surface mixed layer. Surface to bottom temperature differences, which varied from $<$0.05° to ~0.60°C on 13 April, increased correspondingly to between 1.00 and 1.75°C on 19-21 April. Vertical gradients in salinity were relatively small, (up to 0.10%), but frequently showed complex structures with the saltiest water either in the surface or bottom layers.

(b) Phytoplankton - The stabilisation of the surface water, together with high initial levels of inorganic nutrients, provided very favourable conditions for the growth of phytoplankton. Levels of chlorophyll a at the surface, which ranged between 0.9 and 4.1 mg m^{-3} on 13 April, were $>$10 mg m^{-3} over much of the survey area on 19 and 21 April. The highest observed value was 14.8 mg m^{-3}. About 150 determinations of chlorophyll a were made for calibrating the Chelsea (batfish) and Turner (laboratory) fluorometer records. The batfish data should allow a detailed analysis to be made of the temporal and spatial changes in the total standing crop of chlorophyll a, and also of the vertical distribution of chlorophyll a in relation to the density structure.

The phytoplankton bloom was dominated by diatoms, in particular a Nitzschia sp. which gave cell counts up to 4000 ml^{-1}. Measurement of photosynthetic carbon fixation in a deck incubator showed maximum values of 30 mg C $m^{-1}l^{-1}$, but assimilation numbers were surprisingly low (2-3 mg C mg Chl a^{-1} l^{-1}). As the bloom developed the extinction coefficient, as derived from Secchi disc measurements, increased from 0.12 to 0.24m^{-1}.

Samples or particulate material for a range of chlorophyll concentrations (0.2 to 12.1 mg m^{-3}) were collected onto glass fibre pads and frozen for determinations of C, N, P and total lipid. These data, together with information on rates of photosynthesis and depletion of inorganic nutrients, will be used to calculate the growth rates of the phytoplankton.

(c) Inorganic nutrients - Although certain difficulties were experienced with the autoanalyser system, particularly on the Si and NH_3 channels, almost complete records for all four nutrients were obtained on each of the three surveys. Bottle samples were also collected for laboratory determinations of inorganic phosphate, and total dissolved nitrogen and phosphorus. Nitrate was depleted rapidly in the surface water as the diatom population built up, with average concentrations falling from about 6.0μg at -N 1^{-1} on 13 April to 1.0μg at -N 1^{-1} on 19 April. Marked decreases in Si levels were not apparent until 21 April, whereas NO_2 and NH_3 varied little over the whole period.

2. Shelf Edge Survey

This survey demonstrated the existence of two temperature fronts, one associated with the shelf edge and the other in deeper water. The total change of temperature across both fronts was 0.5°C with a consequent density change of 0.045 sigma-t units. Both fronts extended down to at least 60m at a slope of about 2° to the horizontal. Both chlorophyll and nutrients showed either no change or a very small change across the front. However the chlorophyll levels were extremely low (0.2-0.3 mg/m³) and evidence suggested that this area was still in a pre-bloom condition. It was also observed that over a period of two days the spatial sharpness of the front decreased considerably.

APPENDIX 1. DETAILS OF SURVEY LEGS

LEG NO.	DATE 1979	START TIME (GMT)	START POSITION		END TIME (GMT)	END POSITION		COMMENTS
1	11/iv	1530	51°18.6'N	4°46.2'W	0610	51°10.3'N	7°57.7'W	No Batfish.
2	12/iv	1704	51° 8.9'N	8°16.0'W	2029	51°10.1'N	7°33.5'W	Batfish working
3		2220	51°10.4'N	7°33.9'W	0233	51°21.1'N	6°55.7'W	Start of Nymphe Bank survey 1.
4	13/iv	0239	51°21.0'N	6°55.1'W	0326	51°16.8'N	6°50.3'W	
5		0333	51°16.4'N	6°50.4'W	0816	51° 4.4'N	7°32.4'W	
6		0821	51° 4.0'N	7°32.7'W	0900	50°59.5'N	7°30.2'W	
7		0906	50°59.3'N	7°29.5'W	1331	51°11.0'N	6°48.9'W	
8		1343	51°10.5'N	6°47.3'W	1421	51° 6.6'N	6°43.8'W	
9		1426	51° 6.2'N	6°44.0'W	1827	50°55.2'N	7°22.9'W	
10		1833	50°54.8'N	7°23.1'W	1915	50°50.0'N	7°20.3'W	
11		1922	50°49.8'N	7°19.6'W	2327	51° 0.6'N	6°41.1'W	End of main Nymphe Bank survey 1.
12		2334	51° 1.1'N	6°40.9'W	0104	51°10.8'N	6°47.5'W	
13	14/iv	0111	51°11.1'N	6°48.2'W	0514	51°10.5'N	7°32.1'W	Back at N.W. corner of grid.
14		1515	50°59.9'N	8° 5.9'W	2038	49° 7.9'N	11°33.7'W	Batfish down 1715-2232h. On course for shelf edge.
15	15/iv	2039	49° 7.8'N	11°33.7'W	0225	48°29.9'N	11°31.1'W	
16	16/iv	0235	48°29.2'N	11°30.2'W	0445	48°29.5'N	11° 8.1'W	
17		0500	48°29.6'N	11° 5.7'W	0950	48°59.4'N	10°47.9'W	
18		1000	48°59.4'N	10°48.3'W	1123	48°52.1'N	10°57.8'W	
19		1133	48°52.3'N	10°58.7'W	1325	49° 4.2'N	10°59.0'W	Leg ended by batfish fault.
20		1930	49° 7.0'N	11° 1.4'W	2100	49° 0.2'N	11°11.2'W	
21		2102	49° 0.2'N	11°11.3'W	2327	49°15.1'N	11°12.4'W	
22		2333	49°15.5'N	11°12.9'W	0225	49°14.9'N	11°38.3'W	Batfish hauled to ship for calibration at 0147h.
23	17/iv	0234	49°15.6'N	11°38.8'W	0547	49°30 5'N	11°15.4'W	
24		0551	49°30.7'N	11°14.8'W	0714	49°31.2'N	11° 0.6'W	
25		0715	49°31.1'N	11° 0.6'W	0740	49°29.1'N	11° 3.5'W	
26		0800	49°28.3'N	11° 4.6'W	1235	49° 5.3'N	11°34.9'W	
27		1310	49° 4.2'N	11°35.0'W	1518	48°53.4'N	11°21.3'W	
28		1600	48°54.6'N	11°18.8'W	1659	48°59.8'N	11°12.4'W	
29		1700	48°59.9'N	11°12.3'W	1900	49° 8.7'N	10°55.7'W	
30		1900	48° 8.7'N	10°55.7'W	0908	50° 4.5'N	9° 1.5'W	Run ended by batfish malfunction
31	18/iv	2300	50°50.0'N	7°20.5'W	0010	50°52.8'N	7°11.0'W	Batfish down 0011-0040h.
32	19/iv	0040	50°53.1'N	7° 9.3'W	0323	50°58.9'N	6°44.5'W	Start of second Nymphe Bank Survey
33		0330	50°59.4'N	6°44.3'W	0408	51° 2.9'N	6°47.3'W	
34		0414	51° 3.1'N	6°48.1'W	0750	50°53.6'N	7°22.0'W	

LEG NO.	DATE 1979	START TIME (GMT)	START POSITION		END TIME (GMT)	END POSITION		COMMENTS
35	19/iv	0757	50°53.9'N	7°22.8'W	0854	51°00.0'N	7°26.3'W	
36		0900	51° 0.4'N	7°25.9'W	1249	51°11.0'N	6°47.3'W	
37		1255	51°11.5'N	6°46.9'W	1340	51°16.1'N	6°50.0'W	
38		1346	51°16.3'N	6°50.6'W	1814	51° 5.1'N	7°30.5'W	
39		1820	51° 5.3'N	7°31.1'W	1900	51° 9.4'N	7°33.8'W	
40		1910	51°10.1'N	7°33.2'W	2310	51°21.4'N	6°54.5'W	
41		2322	51°21.7'N	6°54.5'W	0538	51° 3.8'N	7°55.5'W	
42	20/iv	0550	51° 3.4'N	7°55.2'W	0810	51°10.8'N	7°33.6'W	End of second Nymphe Bank Survey
43		2316	50°50.9'N	7°16.5'W	0240	51° 0.2'N	6°42.5'W	Start of third Nymphe Bank Survey
44	21/iv	0300	51° 1.8'N	6°41.4'W	0340	51° 5.6'N	6°44.2'W	
45		0346	51° 5.9'N	6°44.9'W	0740	50°55.4'N	7°22.5'W	
46		0750	50°55.1'N	7°23.9'W	0830	50°58.8'N	7°27.1'W	
47		0840	50°59.4'N	7°26.6'W	1242	51°11.1'N	6°48.0'W	
48		1250	51°11.7'N	6°47.7'W	1330	51°15.8'N	6°50.4'W	
49		1336	51°16.0'N	6°51.0'W	1733	51° 5.2'N	7°29.9'W	
50		1740	51° 5.4'N	7°30.9'W	1816	51° 9.4'N	7°33.9'W	
51		1822	51° 9.9'N	7°33.5'W	2125	51°17.9'N	7° 4.0'W	Batfish fault
52		2340	51°18.6'N	7° 0.3'W	0026	51°20.8'N	6°54.7'W	End of third Nymphe Bank Survey
53	22/iv	0030	51°21.0'N	6°54.1'W	0442	51°21.1'N	6° 9.0'W	Leg ended by batfish fault
54		0613	51°20.7'N	6° 9.6'W	1118	51°18.8'N	5°16.7'W	End of sampling.

APPENDIX 2 VERTICAL CTD AND PUMP PROFILES

Unless otherwise stated the following variables were sampled: temperature, conductivity, fluorescence, oxygen and nutrient concentrations and light irradiance.

DIP NO.	DATE 1979	START TIME (GMT)	END TIME (GMT)	POSITION		DEPTH (M)	COMMENTS
0	14/iv	0603	0845	51°10.7'N	7°35.2'W	0-70	Fluorescence, oxygen and nutrients only.
1	14/iv	1126	1143	51°11.1'N	7°40.3'W	0-70	
2	14/iv	1148	1211	51°11.1'N	7°41.1'W	40-0	Stopping every 2m.
3	14/iv	1214	1228	51°11.1'N	7°41.1'W	0-40	
4A	17/iv	0750	0752	49°28.8'N	11°4.0'W	0-150	Batfish dip, temperature, conductivity and fluorescence only
4B	17/iv	1235	1253	49°5.0'N	11°35.1'W	0-150	" " " "
4C	17/iv	1525	1541	48°53.3'N	11°20.6'W	0-150	" " " "
5	20/iv	1101	1145	51°10.3'N	7°31.4'W	0-75	
6	20/iv	1151	1221	51° 9.9'N	7°30.7'W	30-4	Stopping every 2m
7	20/iv	1223	1227	51° 9.8'N	7°30.4'W	0-30	
8	20/iv	1321	1336	51°4.2'N	7°30.2'W	0-60	
9	20/iv	1337	1402	51°4.0'N	7°30.0'W	36-4	Stopping every 2m.
10	20/iv	1518	1520	50°59.6'N	7°27.7'W	0-60	
11	20/iv	1527	1556	50°59.4'N	7°27.3'W	36-4	Stopping every 2m.
12	20/iv	1652	1659	50°54.7'N	7°23.3'W	0-60	
13	20/iv	1700	1729	50°54.7'N	7°23.3'W	36-4	
14	20/iv	1730	1739	50°54.7'N	7°22.6'W	0-40	
15	20/iv	1833	1846	50°50.1'N	7°19.5'W	0-60	
16	20/iv	1847	1922	50°50.2'N	7°19.5'W	36-4	Stopping every 2m.

FIGURE CAPTIONS

Fig. 1.	Schematic diagram of sensors, data loggers and PDP 11/34 computer.
Fig. 2.	Track chart for the whole cruise.
Fig. 3.	Track chart for the first Nymphe Bank survey.
Fig. 4.	Track chart for the survey of the shelf edge in the vicinity of the Goban Spur.
Fig. 5.	Track chart for the second Nymphe Bank survey.
Fig. 6.	Track chart for the third Nymphe Bank survey.

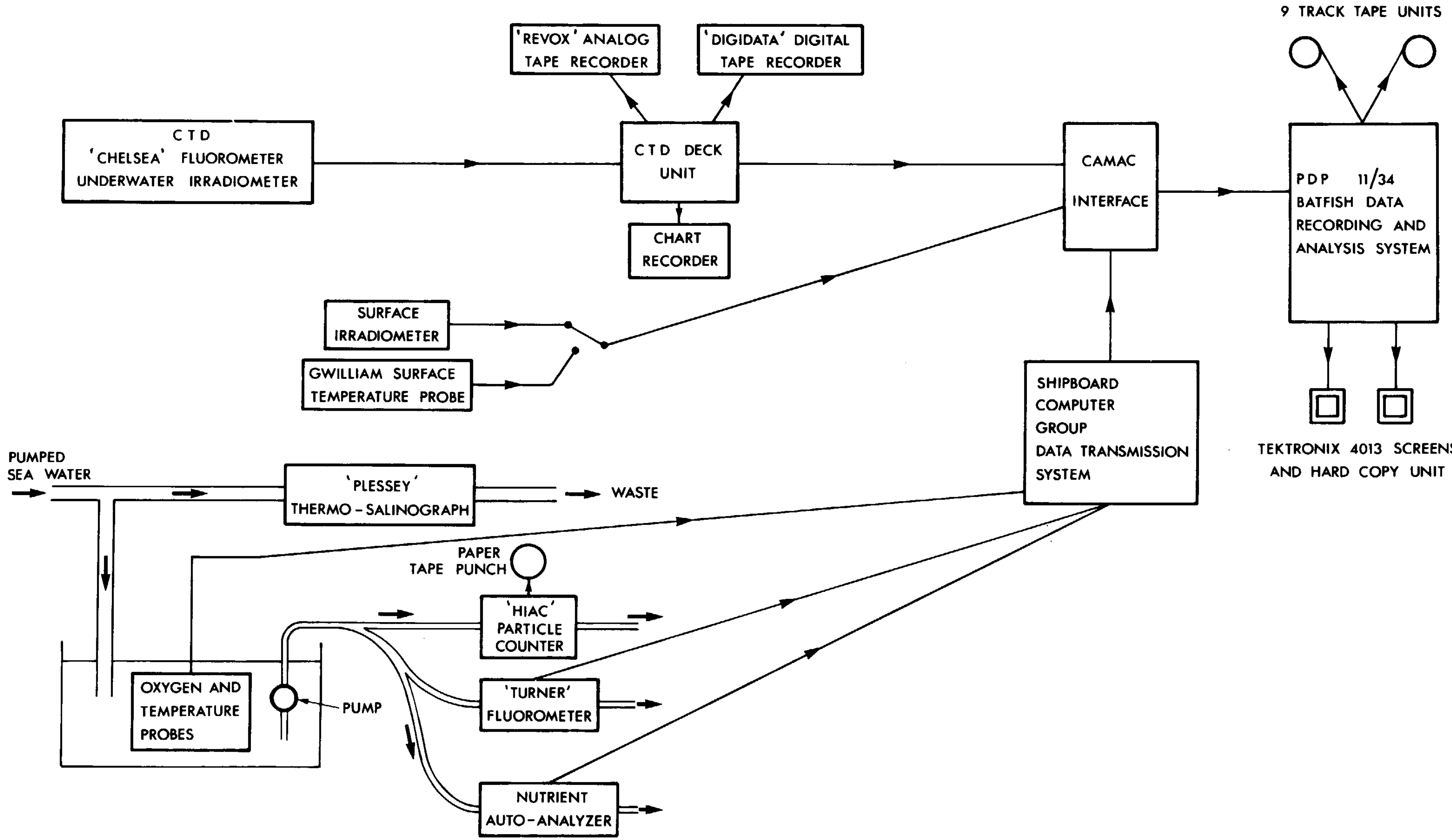
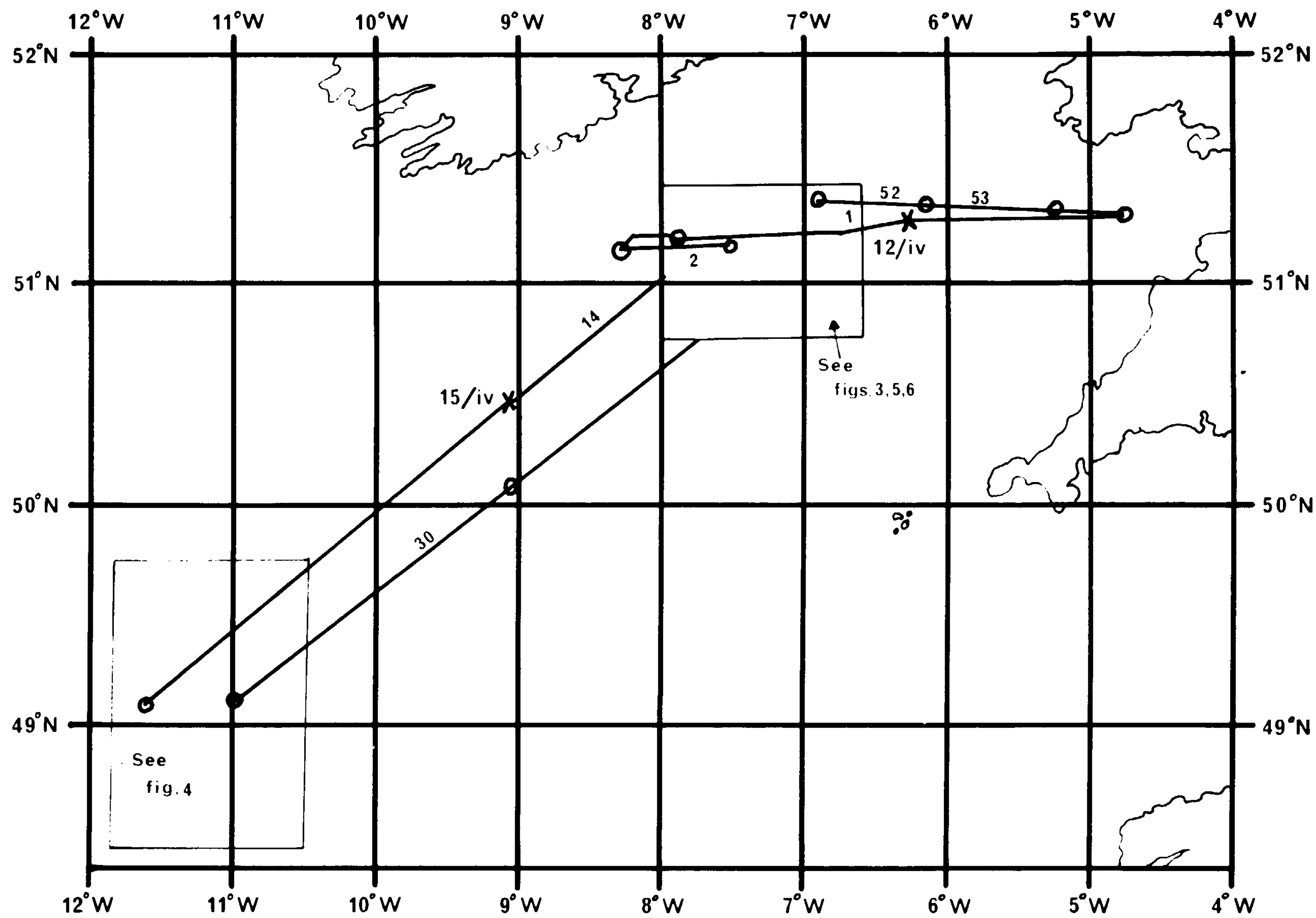

CTD
'CHELSEA' FLUOROMETER
UNDERWATER IRRADIOMETER
'REVOX' ANALOG TAPE RECORDER
'DIGIDATA' DIGITAL TAPE RECORDER
CTD DECK UNIT
CHART RECORDER
CAMAC INTERFACE
9 TRACK TAPE UNITS
PDP 11/34 BATFISH DATA RECORDING AND ANALYSIS SYSTEM
SURFACE IRRADIOMETER
GWILLIAM SURFACE TEMPERATURE PROBE
SHIPBOARD COMPUTER GROUP DATA TRANSMISSION SYSTEM
TEKTRONIX 4013 SCREENS AND HARD COPY UNIT
PUMPED SEA WATER
'PLESSEY' THERMO-SALINOGRAPH
WASTE
PAPER TAPE PUNCH
'HIAC' PARTICLE COUNTER
OXYGEN AND TEMPERATURE PROBES
PUMP
'TURNER' FLUOROMETER
NUTRIENT AUTO-ANALYZER

Fig. 1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11°W
10°W
9°W
8°W
7°W
6°W
5°W
4°W
52°N
51°N
50°N
49°N
52
53
1
2
12/iv
14
15/iv
30
See
figs. 3, 5, 6
See
fig. 4

Fig. 2

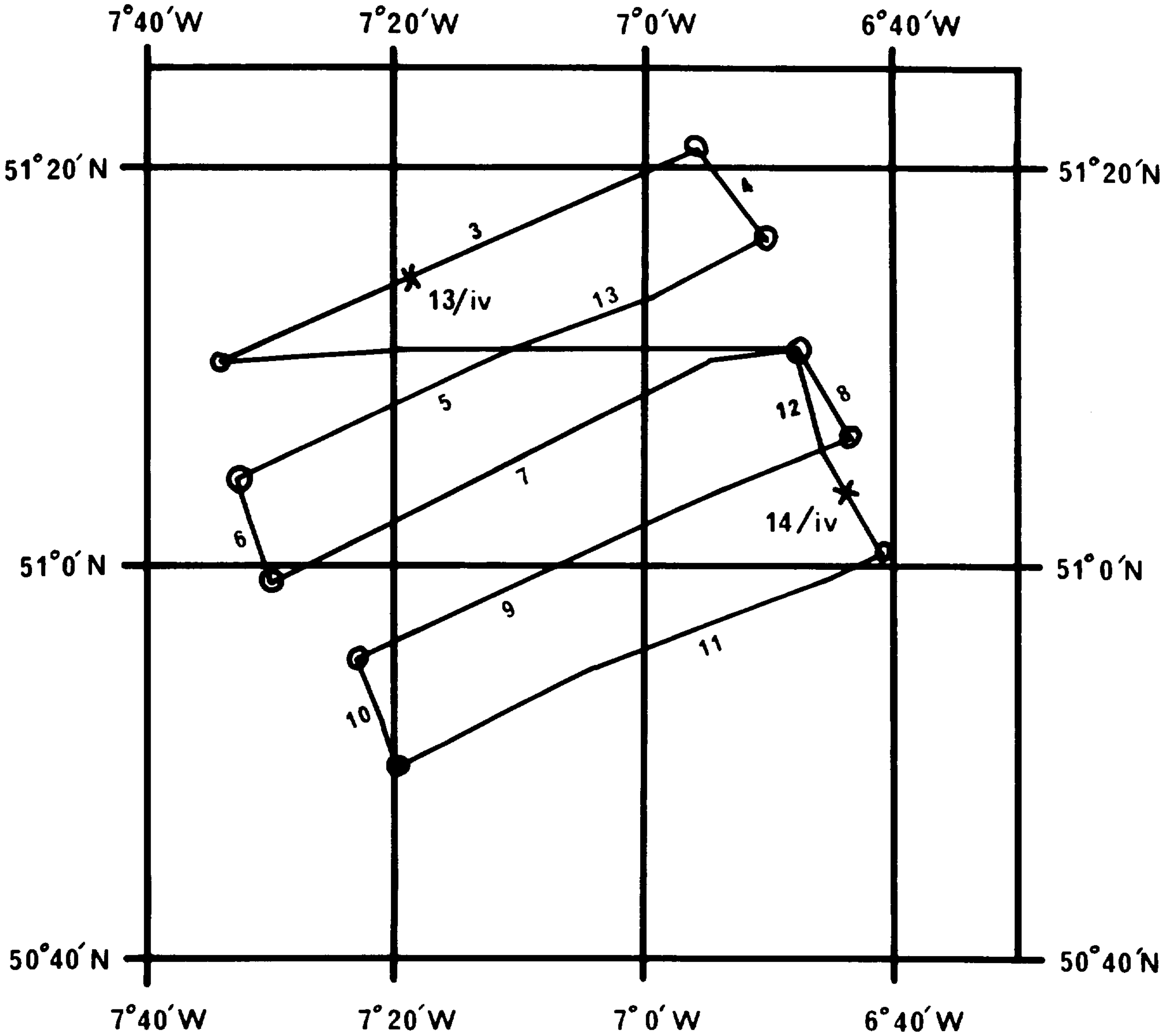
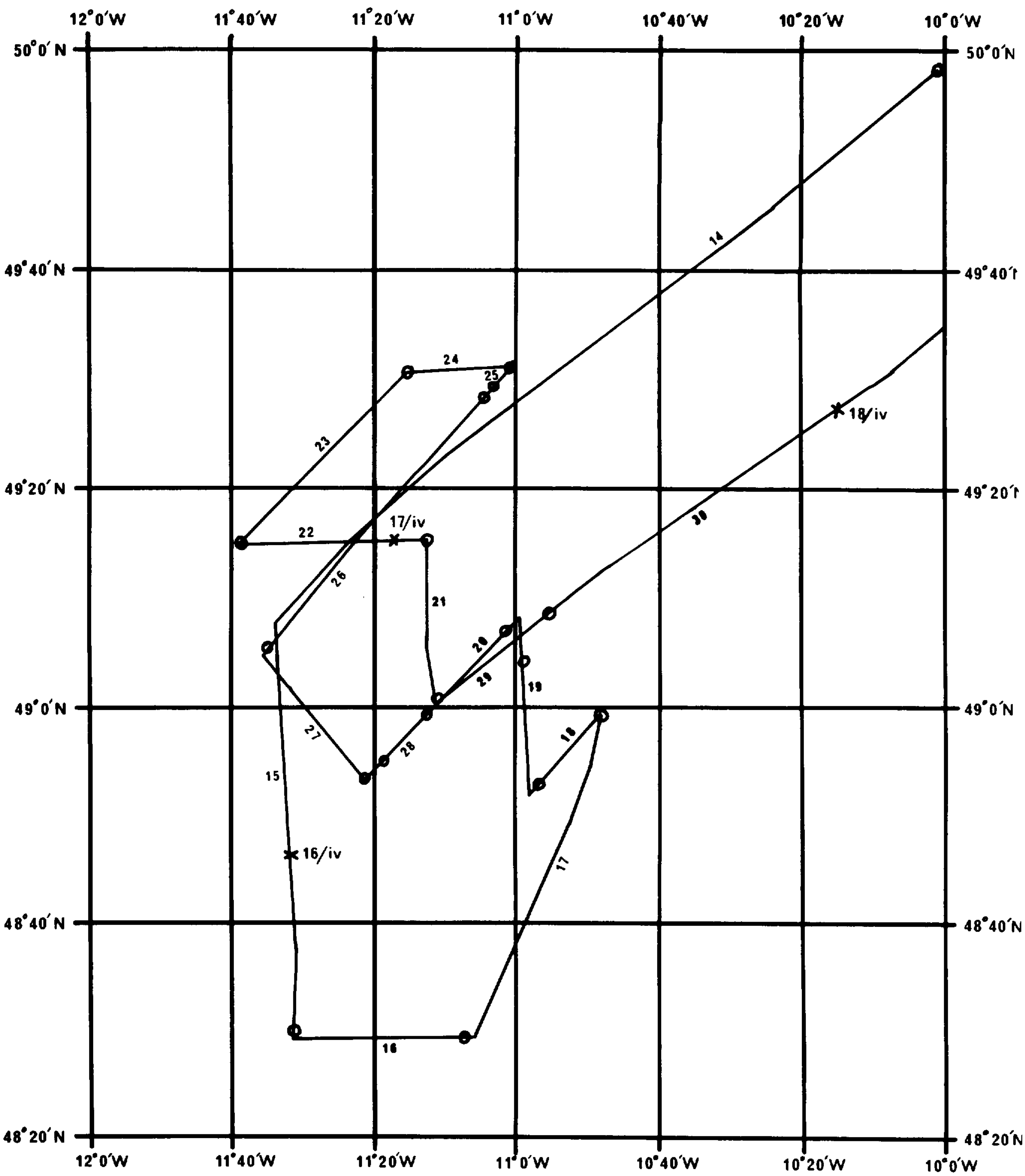

7°40'W
7°20'W
7°0'W
6°40'W
51°20'N
51°0'N
50°40'N
3
4
13/iv
13
5
6
7
8
12
14/iv
9
10
11

Fig. 3



12°0'W
11°40'W
11°20'W
11°0'W
10°40'W
10°20'W
10°0'W
50°0'N
49°40'N
49°20'N
49°0'N
48°40'N
48°20'N
14
15
16
17
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22
23
24
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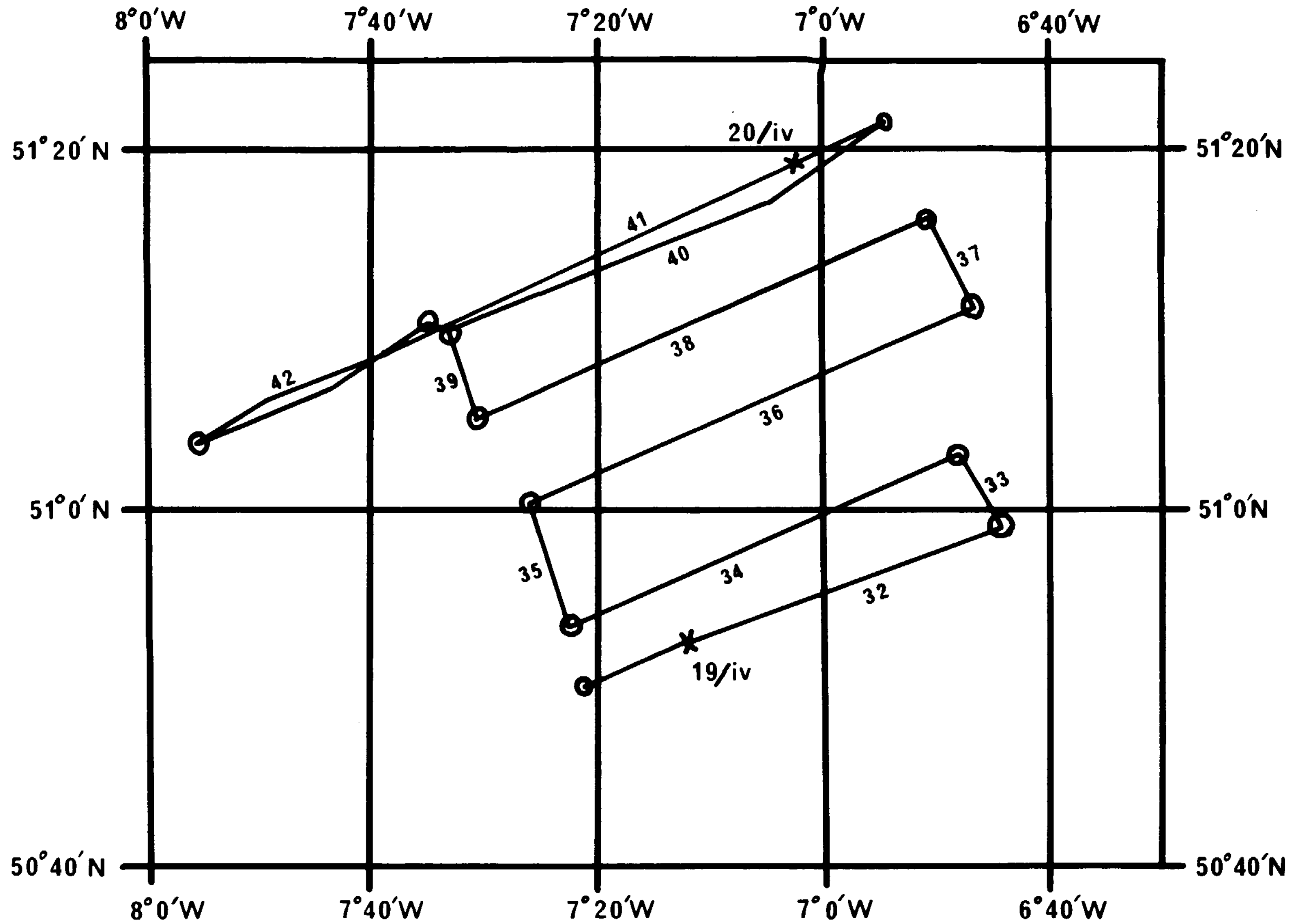
26
27
28
29
30
16/iv
17/iv
18/iv

Fig. 4


8°0′W
7°40′W
7°20′W
7°0′W
6°40′W
51°20′N
51°0′N
50°40′N
20/iv
19/iv
32
33
34
35
36
37
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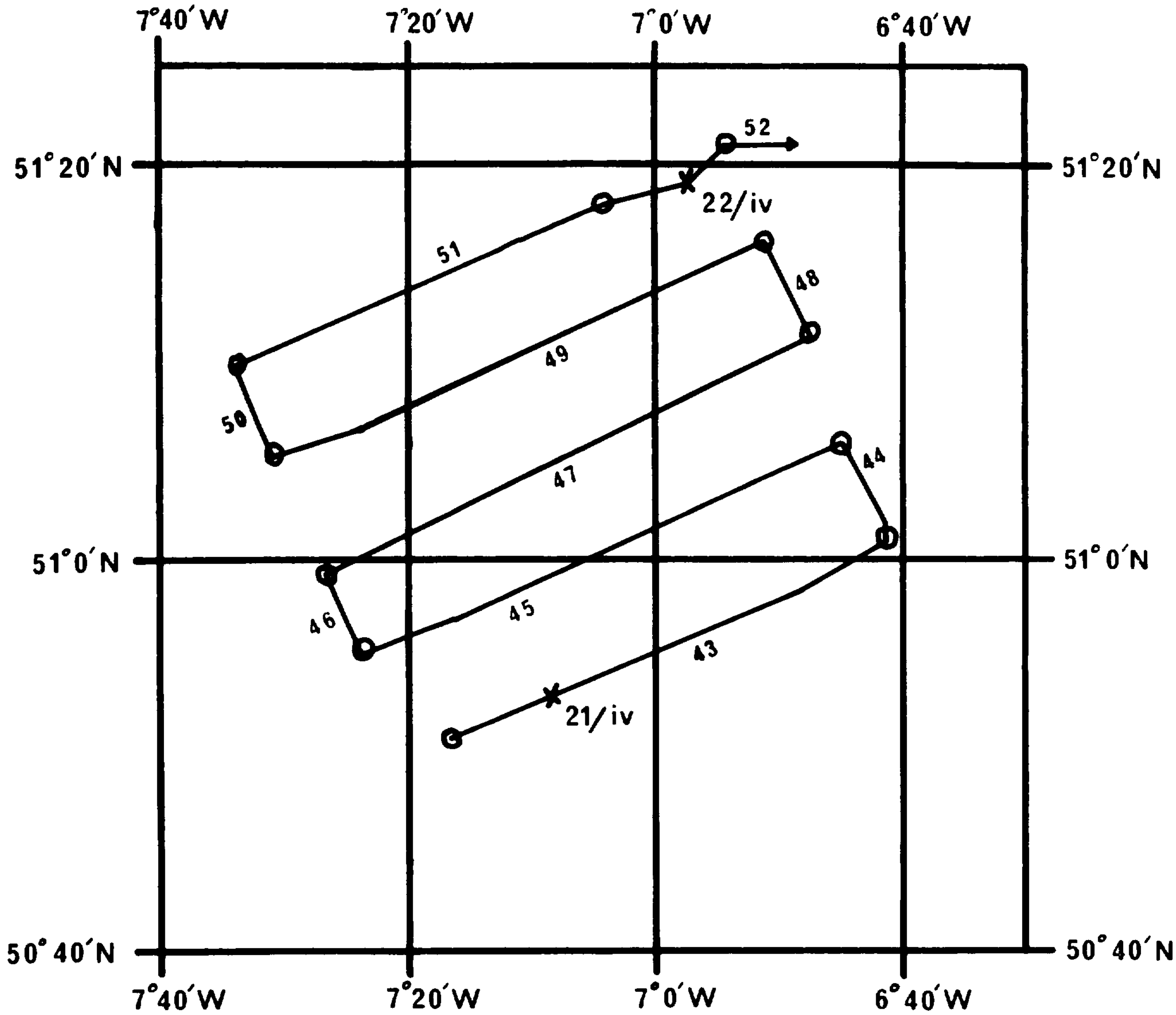
39
40
41
42

Fig. 5



7°40′W
7°20′W
7°0′W
6°40′W
51°20′N
51°0′N
50°40′N
52
22/iv
51
48
49
50
47
44
46
45
43
21/iv

Fig. 6

CRUISE REPORTS

RRS DISCOVERY

CRUISE NO		REPORT NO
1	JUN - AUG 1963	1*
2	AUG - DEC 1963	2*
3	DEC 1963 - SEP 1964	3*
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4	FEB - MAR 1965	4
TO	TO	TO
37	NOV - DEC 1970	37
38	JAN - APR 1971	41
39	APR - JUN 1971	40
40	JUN - JUL 1971	48
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42	SEP 1971	49
43	OCT - NOV 1971	47
44	DEC 1971	46
45	FEB - APR 1972	50
46	APR - MAY 1972	55
47	JUN - JUL 1972	52
48	JUL - AUG 1972	53
49	AUG - OCT 1972	57
50	OCT 1972	56
51	NOV - DEC 1972	54
52	FEB - MAR 1973	59
53	APR - JUN 1973	58
		IOS CR***
54	JUN - AUG 1973	2
55	SEP - OCT 1973	5
56	OCT - NOV 1973	4
57	NOV - DEC 1973	6
58	DEC 1973	4
59	FEB 1974	14
60	FEB - MAR 1974	8
61	MAR - MAY 1974	10
62	MAY - JUN 1974	11
63	JUN - JUL 1974	12
64	JUL - AUG 1974	13
65	AUG 1974	17
66	AUG - SEP 1974	20
68	NOV - DEC 1974	16
69	JAN - MAR 1975	51
73	JUL - AUG 1975	34
74/1+3		35
	SEP - OCT 1975	
74/2		33
75	OCT - NOV 1975	43
77	JUL - AUG 1976	46
78	SEP - OCT 1976	52
79	OCT - NOV 1976	54
82	MAR - MAY 1977	59
83	MAY - JUN 1977	61
84	JUN - JUL 1977	60
86	SEP 1977	57
87	OCT 1977	58
88	OCT - NOV 1977	65
89	NOV - DEC 1977	67
90	JAN - MAR 1978	68
91	MAR 1978	69
92	APR - MAY 1978	70
93	MAY - JULY 1978	71
94	JULY - SEPT 1978	74
95	OCT - NOV 1978	77
97	DECEMBER 1978	77
98	DEC 1978 - JAN 1979	75
99	JANUARY 1979	78

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** NIO CR: NATIONAL INSTITUTE OF OCEANOGRAPHY, CRUISE REPORT

*** IOS CR: INSTITUTE OF OCEANOGRAPHIC SCIENCES, CRUISE REPORT

CRUISE REPORTS

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AUG - SEP 1975	IOS CR 41
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APR 1975	IOS CR 39
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